

[54] **NON-WOVEN WEBS OF FILAMENTS OF SYNTHETIC HIGH MOLECULAR WEIGHT POLYMERS AND PROCESS FOR THE MANUFACTURE THEREOF**

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[58] Field of Search..... 264/168, 177 F, 210 F; 161/150, 170, 173; 156/167, 180, 181, 183; 428/225, 288, 296, 371, 910, 357; 28/72.1

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[57]

ABSTRACT

Apparatus and process for the manufacture of a non-woven web. The web consists of filaments of strands of filaments which show helical crimping with alternating directions of turn of the helices within the filament. Preferred outlets are floor coverings, cover materials and filter mats.

4 Claims, 8 Drawing Figures

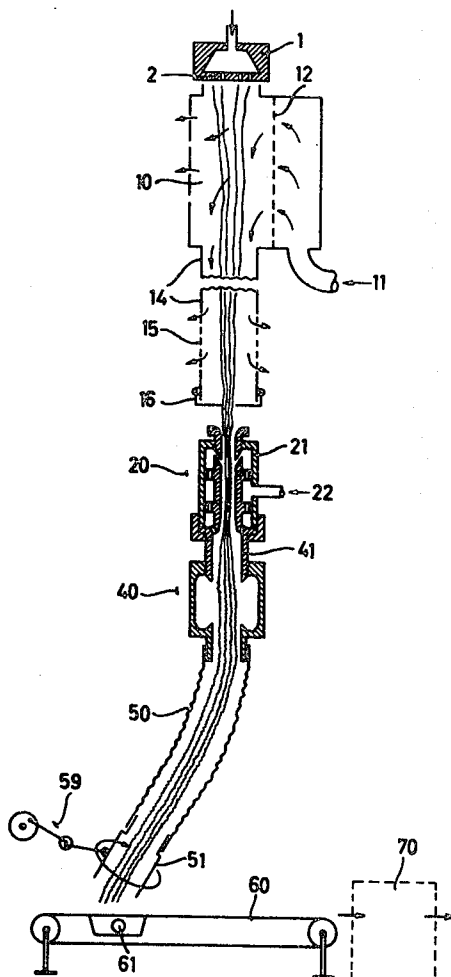


Fig. 1

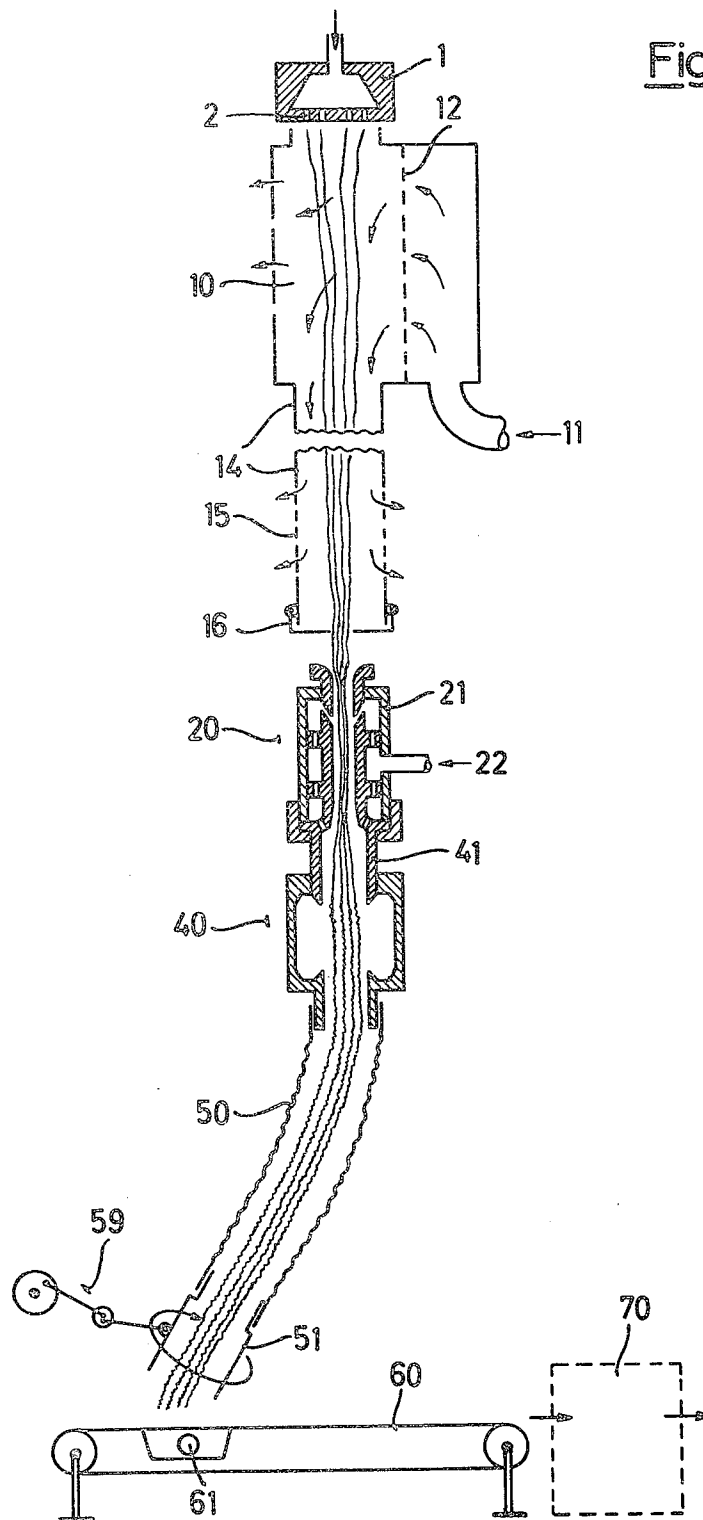


Fig. 2a

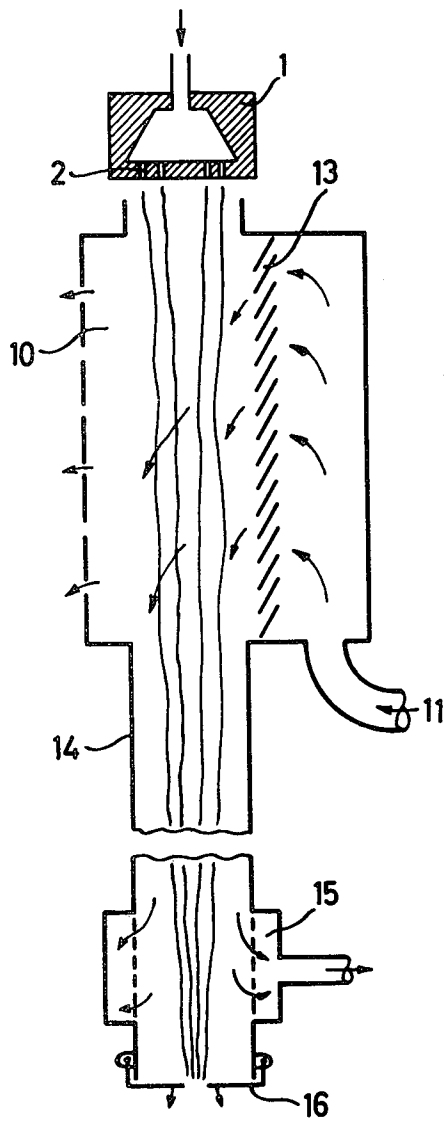


Fig. 2b

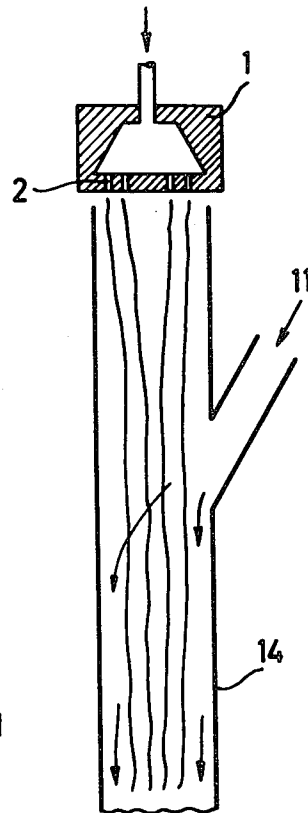


Fig. 2c

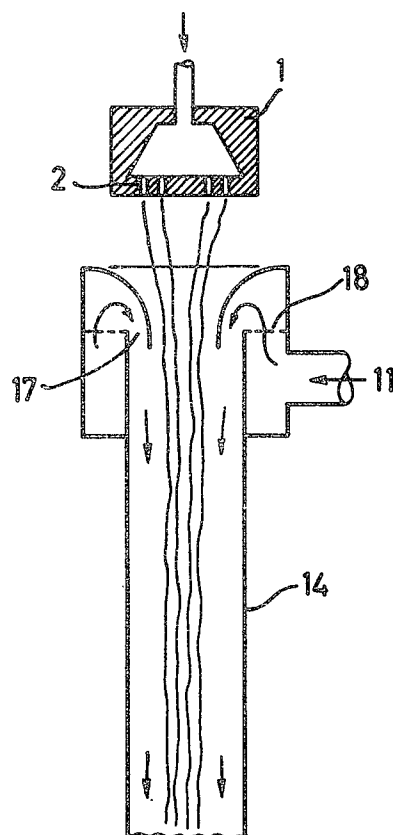
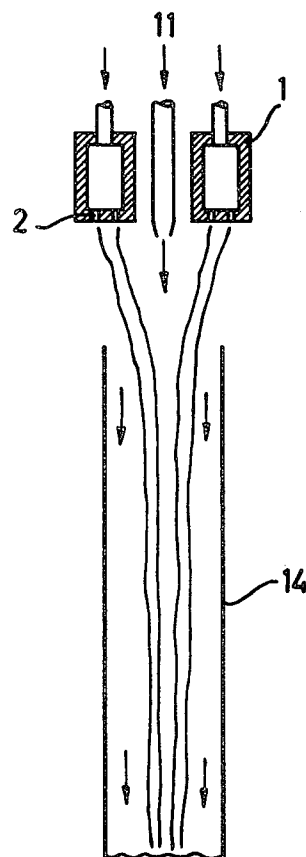


Fig. 2d



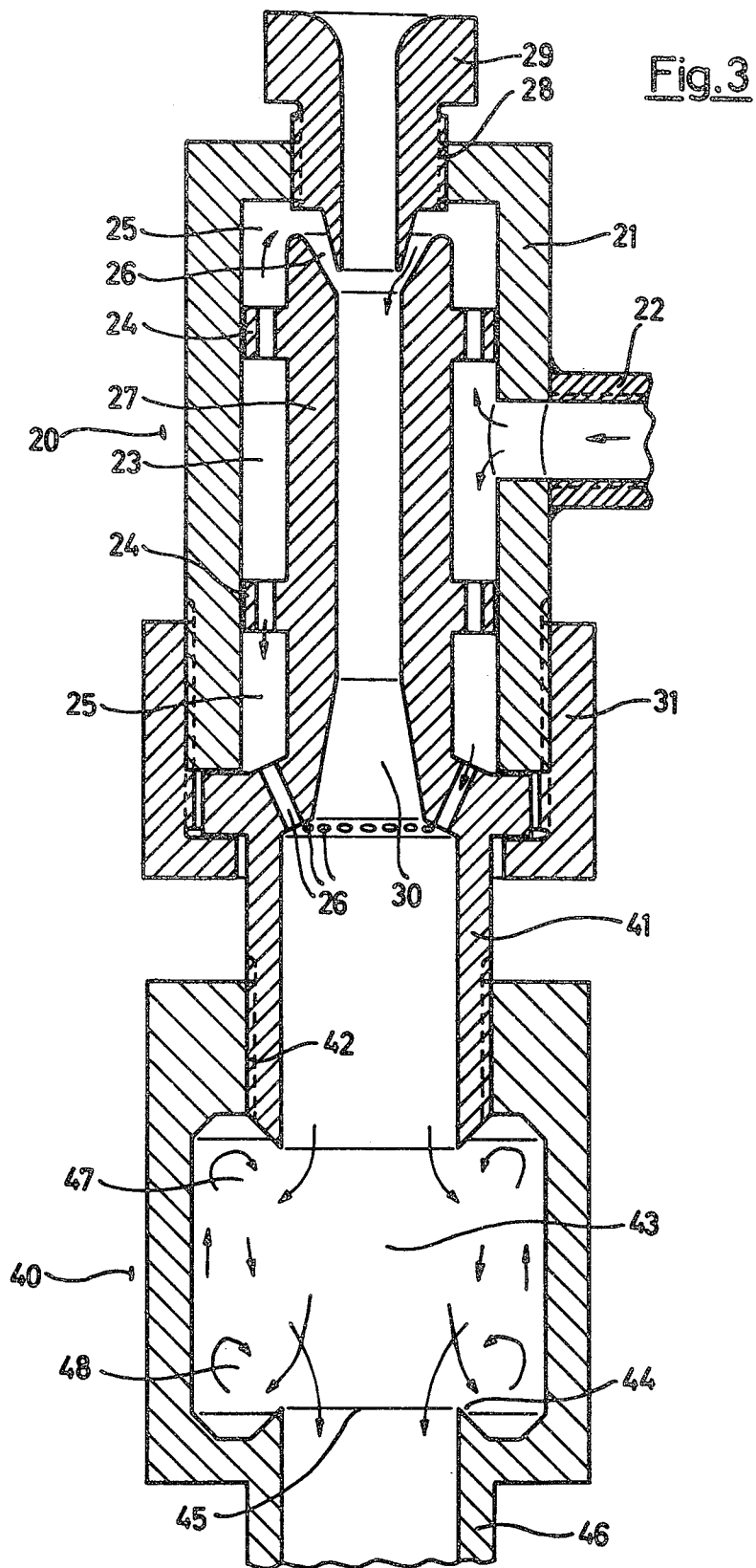


Fig.4

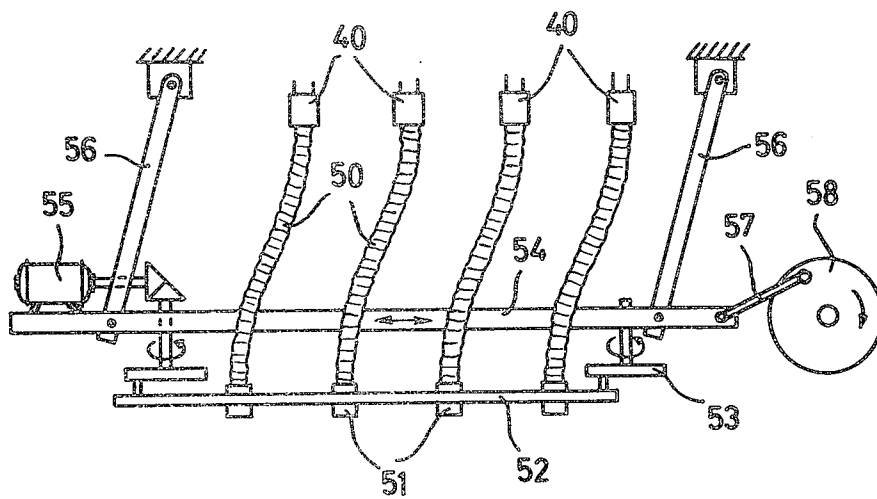
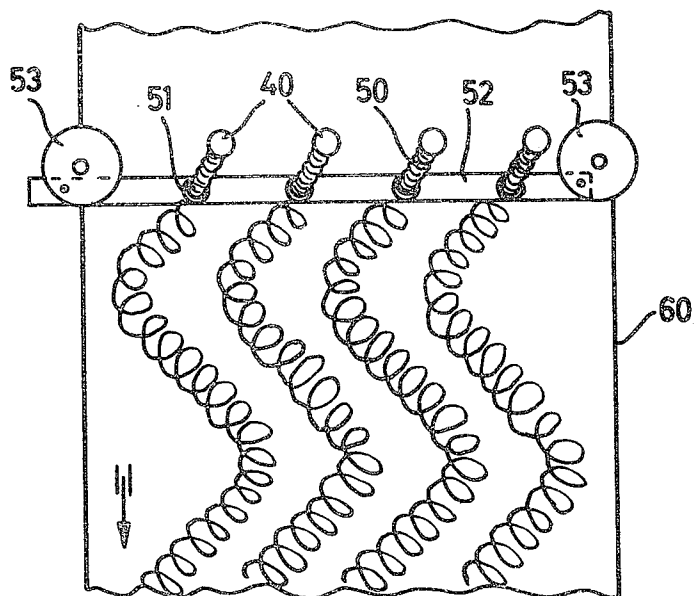


Fig.5



NON-WOVEN WEBS OF FILAMENTS OF SYNTHETIC HIGH MOLECULAR WEIGHT POLYMERS AND PROCESS FOR THE MANUFACTURE THEREOF

The present invention relates to a non-woven web of filaments or strands of filaments of synthetic high molecular weight polymers, in which the filaments or strands of filaments — hereinafter referred to as the filaments — are laid down in looped configurations. The invention also relates to a process and apparatus for the manufacture of such webs.

It is well known that a filament, a group of filaments or a bundle of filaments coming from a conventional or specially designed spinneret may be taken up by a pneumatic jet or aspirator jet of a variety of types and transported to a lay-down area where a tangled web is produced by turbulent air.

Japanese Pat. No. 45-5057 describes a process for the manufacture of non-woven fabrics which uses conventional single-stage pneumatic jets having a circular cross-section and adapted to take up the filaments immediately after spinning or after mechanical stretching. These simple pneumatic jets are moved transversely across a moving belt, which procedure clearly leads to a web in which the filaments are predominantly transversely oriented. Such transverse orientation is inconvenient in most cases, as it produces variations in the properties of the web in the different directions in its plane. Another drawback of this process is that, the filament being uncrimped, only webs of a low specific volume can be obtained.

U.S. Pat. No. 3,117,055 describes non-woven fabrics consisting of crimped filaments which have been bonded together with a bonding agent by a special procedure. The fabrics are produced by causing a single-stage aspirator jet to take up filaments issuing from the spinneret. The aspirator jet is charged with static electricity so that the filaments are also charged and repel each other on leaving the aspirator jet. As a result, some of the suction medium can escape laterally and there is a reduction in the axial speed producing only slight compression of the filaments. Consequently, the filaments passing to the web are crimped only slight and irregularly. The use of electrostatic charges in this process adds to its cost.

The disadvantages and shortcomings discussed above with reference to the cited prior art may be added to by the following drawbacks which occur in some cases: some of the filaments form fused lumps while still hot, due to insufficient cooling; operational safety is inadequate; the melt and air distribution over the length or width of the nozzles and channels are very uneven; the specific gas or energy consumption is uneconomically high; the degrees of stretch obtained (strength properties and elongation) are inadequate, or only smooth filaments can be obtained.

It is an object of the invention to provide an economical process for the manufacture of a non-woven material which is superior to known non-woven materials as regards specific volume, resilience and recovery, damping properties and yield or slip characteristics of the filaments during, for example, needle punching or tufting operations.

In accordance with the present invention, this object is achieved by providing each filament forming the fabric with helical crimping showing alternating direc-

tions of turn along the length of the filament, even if the latter is in a strand, the diameter of the helices being from 1 to 10 mm and the changes in the direction of turn thereof occurring after every 1 to 50 and preferably after every 5 to 15 turns.

According to a preferred embodiment of the invention, the filaments forming the web are laid down in the form of perfect or imperfect trochoids, which trochoids show regular or random variations of orientation.

Preferably, the web-forming filaments are of polypropylene, polyester, polyamide, polyethylene or polyurethane. They may be needle-punched, thermally bonded or bonded by means of dispersions of bonding agents such as polyacrylates.

It is a further object of the invention to provide a process for the manufacture of the non-woven webs of the invention from filaments of synthetic high molecular weight polymers by extrusion of filament-forming melts through spinnerets having a plurality of holes in a circular, elliptical or linear arrangement, which process is characterized in that

- a. cooling air is caused to impinge on the extruded filaments from one side at an angle of from 0° to 90° to the direction of travel of the filaments, all or at least part of which air is deflected to a direction of flow parallel to the filaments, by which means the filaments are cooled and a primary take-up of the filaments is effected;
- b. at the end of the cooling zone, substantially all of the cooling air is allowed to escape from or is sucked away from the filaments;
- c. the filaments, substantially free from cooling air, are subjected to the main take-up forces in a take-up zone which is immediately downstream of the cooling zone and is in the form of a single-stage or, preferably, multi-stage pneumatic jet;
- d. after stretching, the partially plastic filaments are crimped by periodic alteration of the position of one or more annular or cylindrical vortices of gaseous medium along the filaments at a high frequency with partial flow-off and replenishment of the vortex or vortices;
- e. if desired, the laid-down web is bonded by mechanical, thermal or chemical means by known methods.

During crimping, the filaments are normally partially plastic, which means that the pneumatic jets may be operated with cold air. If the filaments are over-cooled in the cooling zone, crimping may be achieved by using hot air or steam in the pneumatic jet. The crimps may be fixed by allowing the crimped filaments to relax under conditions of cooling to below their softening point. The use of steam in the cooling zone can influence the strength properties and resilience of the filaments and also the type of crimping obtained.

It is a further object of the invention to provide an apparatus for carrying out the process of the invention, which apparatus is characterized by:

- a. one or more spinnerets of a circular, oval or rectangular shape, each having a plurality of holes;
- b. a cooling channel immediately downstream of said spinnerets and comprising means for feeding and appropriately distributing the cooling air and optionally means for deflecting the air to a direction of flow parallel to the filaments, and a passageway immediately downstream of said cooling channel, the lower end of said passageway having means for allowing the cooling air to escape or be sucked off

and, if desired, flaps for partially closing the outlet cross-section of the passageway;

- c. pneumatic jets downstream of the passageway, preferably of the two-stage or multi-stage type, and consisting of an outer housing having air-feed connections, an equalizing chamber with damming elements and inlet chambers downstream thereof, which inlet chambers communicate with an inner channel via inlets, slots or ducts at an angle of from 5° to 30°, which inner chamber is provided, in its wall, with a screw-adjustable suction nozzle and, in the case of a multistage injector, increases in cross-section from stage to stage, optionally via a diffuser;
- d. a crimping device downstream of the pneumatic jet and consisting of an inlet channel to which there is mounted via means for axial displacement such as a screw-thread connection a member of greater cross-section, for example a tube, the increase in cross-section starting with an undercut and continuing irregularly to form a chamber which ends in an irregular reduction of cross-section leading to sharp edges defining the commencement of a short outlet channel;
- e. flexible connecting members, e.g. flexible tubes, which are connected to the crimping device and are fitted with mouthpieces of constant cross-section or, preferably, of enlarged cross-section;
- f. a moving device to which the mouthpieces are secured;
- g. a moving belt optionally provided with suction means at the point where the filaments initially contact the belt;
- h. optionally, a device for effecting mechanical, thermal or chemical bonding of the web.

The filaments are normally spun by means of spinnerets having a circular, oval, rectangular or similar shape and containing a plurality of spinning holes. Spinnerets may also be used which have free spaces in their central region, through which cooling air may be blown into the bundles of filaments, which cooling air may be thermally screened from the spinnerets if necessary. It has been found convenient, for the purposes of the process of the invention, to pre-orientate the melt before it is extruded by subjecting it to strong shearing strains. The first-mentioned spinning method has the advantage that spinnerets of simple design may be used. The second method using spinnerets with free spaces in the central region still utilizes relatively simple designs compared with complicated spinnerets of special design. Consequently, further advantages of the process of the invention are as follows:

- a. cold air may be used;
- b. the point of impingement of the pneumatic force is not close to the spinning hole but at a distance of at least about 10 mm therefrom, this giving rise to a longer primary take-up zone; and
- c. the ratio of the cross-sectional areas of the melt and air at their respective nozzles is more advantageous, with the result that the specific air consumption is reduced for a given working pressure.

Furthermore, the process of the invention differs from other processes from the manufacture of non-woven webs, for example the processes described in U.S. Pat. No. 3,117,055 and Japanese Pat. No. 45-5057, in that a definite cooling zone is provided, this being divided into sections for the introduction of cooling air and its deflection (if necessary), for parallel

air-flow, and for the removal of the cooling air by suction or escape means. The process of the invention differs from conventional spinning processes which also make use of a definite cooling zone in that the cooling air, which is caused to impinge on the filaments at an angle of from 0° to 90° thereto, is deflected so that a substantial proportion thereof flows parallel to the filaments. The various cooling methods have the common feature of impingement of the cooling air on the filaments from one side and, at least in the second section, strong air flow parallel to the filaments at an independent velocity.

Another important distinguishing feature of the present invention as compared with prior art processes for the manufacture of non-woven webs is evident at the end of the cooling zone, where the cooling air is removed from the process and not transported through the following main take-up means with the filaments. The primary advantage of this embodiment of the process of the invention is that the spatial density of energy is very high for a given consumption of air energy and remains high over the length of the pneumatic jet because only a very small amount of air and not the entire stream of cooling air is sucked into the air jet. Whereas the air used for taking up the filaments in the known processes must also, to a considerable extent, carry out the function of cooling the filaments, cooling is effected in a much more economical manner in the present invention using air at a pressure of from approximately 50 to 200 mm of water, since the air pressure required to take up the filaments must be at least some thousands of mm of water to some atmospheres if satisfactory filament properties are to be achieved. Another advantage resulting from the removal of the cooling air from the system is that when the web is laid down, the amount of air which has to be sucked off is several times (from 5 to 10 times) the amount of air impinging on the moving belt, this being necessary to prevent the web from being dislodged by the blast of air. In the present case therefore, only the relatively small amount of air used for taking up the filaments determines the suction power required, while the generally larger volume of cooling air has already been removed from the filaments before they are taken up.

In the process of the invention, the filaments are taken up by means of, preferably, two-stage or multi-stage pneumatic jets operated by an external air jet. The type of pneumatic jet proposed by the invention makes it possible to operate all stages at an equally high pressure, by which means highly efficient filament take-up is achieved without the apparatus becoming blocking up. The filament take-up apparatus of the invention increases in cross-section from stage to stage in order to accommodate the added volumes of working air. Another distinguishing feature of the single-stage or multi-stage take-up apparatus as compared with prior art devices is that after the air has passed into the outer housing it initially flows into an antechamber where it is uniformly distributed before passing over damming elements and through inlet chambers to the inlet slots or ducts leading to the inner channel containing the filaments.

Immediately downstream of the take-up apparatus there is a crimping device which is distinctly different from prior art devices for crimping filaments, for example for effecting aerodynamic compression crimping, aerodynamic false-twist crimping or crimping in a zone of a medium showing a high degree of irregular turbu-

lence. In the present case, crimping is effected by periodically applying to and removing from the filaments, at a high frequency, one or more annular or cylindrical vortices of a gaseous medium with partial flow-off and replenishment of the vortex or vortices. Crimping is assisted by the previous one-sided cooling of the filaments under the action of the take-up forces.

When the filaments have been crimped, they pass to a diffusor zone where the crimped effect is fixed as the filaments solidify in a relaxed state. To obtain the crimping effect, it is first of all essential to effect proper temperature control in the cooling zone. If the filaments are over-cooled, they can no longer be shaped in the crimping zone unless hot gas or steam is used in the working stream of the aspirator jet. If the filaments are insufficiently cooled, they will adhere to each other in the take-up and crimping zones. If it is desired to open up the bundle of crimped filaments such that the individual crimps are not in phase with each other and the filaments are well separated from each other, it is convenient to operate the final stage of the multi-stage pneumatic jet not with a laminar flow of air but preferably with a plurality of individual air jets emerging from appropriately arranged bores.

The bundles of filaments leaving the pneumatic jets and their associated crimping devices pass through movable elements, for example flexible tubes, to mouthpieces which are moved according to certain kinematic rules so as to describe perfect or imperfect trochoids. In this way, webs are formed on the moving belt and have a structure complying to the said lay-down movements.

The kinematics of the lay-down movements are composed of two superimposed swinging motions, preferably a rotating motion and a linear reciprocating motion effected transversely of the belt and referred to as the transverse motion, the ratio of the frequencies of the rotating and transverse motions being from 2:1 to 100:1 and preferably from 4:1 to 50:1. The amplitudes of the linear transverse motion are advantageously many times greater than the diameter of the rotating motions. The reciprocating transverse motion may cover the entire width of the belt or it may be effected to cover a number of overlapping zones. Depending on the degree to which the bundles of filaments have been opened up, the resulting webs show structures composed of strands of filaments or individual filaments.

The main advantages of the process of the invention are as follows:

1. it involves a simple procedure and uses relatively small units,
2. it is economical and very safe in operation,
3. it produces good filament qualities with relatively uniform thicknesses,
4. it provides the possibility of producing voluminous non-woven webs of crimped filaments having excellent elastic and damping properties.

The various parameters of the process are dimensioned as follows:

Temperature of the melt: depending on the thermoplastic material used, the melts may be spun within various temperature ranges, the upper and lower limits of which may be anywhere in the range defined by the commencement of melting and the maximum temperature possible without the occurrence of chemical changes.

Pressure of melt: the pressures applied to the melt are between about 1 and 150 atmospheres and preferably between 20 and 80 atmospheres gage.

Melt throughput: the throughput through each spinning hole is from 0.1 to 10 g/min and mainly from 1 to 6 g/min. Thus the rate of extrusion of the melt is generally between 0.5 and 15 m/min and preferably between 2 and 10 m/min.

Gas temperature: the temperature of both the cooling air and the take-up air is conveniently in the range of normal room temperatures, that is from 20° to 30°. However, the take-up air may have a temperature of up to about 150°C. if desired, in order to achieve certain crimping characteristics for example. For the same reason, steam or a mixture of air and steam may be used.

Gas pressure: the pressures applied to the cooling air are normally between 20 and 5,000 mm of water and preferably between 50 and 500 mm of water. The take-up air is usually under a pressure of between 0.5 and 50 atmospheres and preferably between 1 and 10 atmospheres gage.

Gas velocities: the velocity of the cooling air is between 1 and 50 and preferably between 2 and 8 m/sec. In the suction tube of the pneumatic jet velocities of from 10 to 500 and preferably from 50 to 200 m/sec may occur. The velocity of the take-up air on entering the inner tube of the pneumatic jet is generally approximately equal to the speed of sound or just below, after which the air undergoes expansion with local supersonic velocities being possible. Subsequent mixture of the take-up air with air drawn in from the atmosphere reduces its velocity to below that of sound and it achieves values between about 100 and 300 m/sec. In the crimping zone this velocity is further reduced to the values between 10 and 100 m/sec.

Specific gas consumption (defined as the ratio of amount of gas to amount of melt in kg/kg or m³/kg (STP): in the case of the main take-up air, this ratio is approximately within the limits 1 to 50 and preferably 5 to 20.

Suitable plastics materials for the process described above are as follows:

1. polyethylene of all densities (0.918 to 0.960 g/cm³) and the copolymers of ethylene with 1-olefins (e.g. propylene and butene), with vinyl esters and acrylic esters (e.g. vinyl acetate copolymers and butyl acrylate copolymers), with additional free acrylic acid groups (e.g. ethylene/t-butyl acrylate/acrylic acid copolymers) and with vinyl chloride. Post-chlorinated polyethylene having a chlorine content of up to 40% is also suitable. The proportion of comonomers in the total polymer may be up to 30% by weight. Polymers in a wide range of molecular weights, measured in terms of melt index (according to ASTM D1238-57 T) are suitable, melt indices $MI_{2.16/190^\circ C}$ being from 1 to 100 and preferably from 5 to 20.

2. Polypropylene and polybutene-1 and their copolymers with each other and with other 1-olefins (e.g. ethylene). The proportion of comonomers may be up to 15% by weight, and the range of molecular weights is as above (melt index range $MI_{2.16/210^\circ C}$ being from 0.1 to 50 and preferably from 1 to 20).

3. Polyamides, for example pure polycondensates of caprolactam or dicarboxylic acids such as adipic and sebacic acids and diamines, for example hexamethylene diamine. Copolymers, for example copolymers of the above starting materials, are also suitable. The

molecular weights, expressed in terms of K values, may vary between $K = 50$ to $K = 90$ and preferably between $K = 70$ to $K = 80$ (K value calculated from the relative viscosity η/η_0 as measured according to German Standard Specification DIN 53,726).

4. Polyesters: particularly suitable are the linear saturated polyesters having average molecular weights between 10,000 and 50,000, such as polyethylene terephthalate (e.g. from terephthalic acid diglycol ester), and the polyesters obtainable from hydroxycarboxylic acids such as ω -hydroxydecanoic acid or 4-(β -hydroxyethoxy)benzoic acid. Apart from this group of polyesters, which may be prepared from only one component, a general group of suitable polyesters comprises the linear saturated polyesters obtainable from glycols and aliphatic or aromatic dicarboxylic acids, provided they give products having the high range of molecular weights specified above. Not only the carboxylic acids but also their anhydrides, esters or acid chlorides may be used.

5. Polyvinyl chloride: homopolymers and copolymers with vinyl esters (e.g. vinyl acetate). Before the processing step, suitable plasticizers should be added, e.g. phthalic esters or adipic esters with monohydric and dihydric alcohols in proportion of up to 40% and preferably from 20 to 30% by weight). Molecular weight range (expressed in K values): 50 to 80.

Before they are converted to filaments, all of the said polymers may have incorporated therein a variety of auxiliaries as used in conventional spinning processes, for example heat stabilizers, light stabilizers, U.V. stabilizers, dyes, flame retardants, crystallization accelerators, etc.

The process described above is capable of producing filaments having the following characteristics:

Filament thicknesses between 1 and 200 μm and preferably between 10 and 100 μm , equivalent to about 1 to 100 g/10,000 m (1 to 100 dtex). The number of helical crimps in the filament is from about 1 to 40 and preferably from 5 to 20 per cm, the diameters of the helices being from about 1 to 10 mm.

Depending on denier, raw materials and conditions of operation, the spinning speeds are between 1,000 and 5,000 m/min, tensile strengths being between between 2 and 6 g/dtex and elongations being between 20 and 300%.

The webs made from the crimped filaments are particularly suitable, on account of their favorable elastic and damping properties, for making carpets and also as filling materials for stuffing mattresses, upholstery, quilts, sleeping bags, anoraks, etc., as insulating mats, tapestries and as backing materials, e.g. for artificial leather, or for use in tires. Other applications include, for example, filters, home furnishings and certain articles of clothing, and also packaging materials, in which latter case webs having only weakly crimped filaments are of primary importance.

Embodiments of the apparatus of the invention are described below with reference to the accompanying drawings in which

FIG. 1 is a diagram of an apparatus for carrying out the process of the invention.

FIG. 2 shows special embodiments of a cooling channel with means for feeding and removing the cooling air.

FIG. 3 illustrates a 2-stage pneumatic jet and a filament crimping zone downstream thereof.

FIG. 4 is an elevation of a preferred embodiment of the lay-down means.

FIG. 5 shows diagrammatically a plan view of the lay-down means shown in FIG. 4 and a non-woven web of the invention.

As shown in FIGS. 1 and 2a to 2c, the filaments are extruded through spinnerets 1 of circular, oval or rectangular shape, or, as shown in FIG. 2d, through spinnerets 1 having a free space in the center. The melt is extruded through a number of spinning holes 2 of circular of profiled cross-section. The ratio of axial length to diameter is preferably at least 2.5 and the center-to-center distance between adjacent holes is at least 5 times and preferably 10 times the diameter of the holes. Depending on the shape of the spinneret, holes 2 are arranged either in concentric circles or ellipses or in straight lines, the free space in the embodiment shown in FIG. 2d being either in the center of the circles or ellipses or between the lines of holes.

The various possibilities of the direction of feed of the cooling air between 90° and 0° to the direction to travel of the filaments are diagrammatically illustrated in FIGS. 1 and 2a to 2d, and the cooling blower (not shown) may operate by suction or by pressure blowing or by both, i.e. by sucking and blowing simultaneously. In FIG. 1, the cooling air impinges on the filaments at right angles to their direction of travel after it has passed through equalizing wire gauze or grid 12. If pressure blowing is used, the side opposite the air inlet 11 may be in the form of, say, a finescreen such that only a small proportion of the cooling air flows horizontally through cooling channel 10, the remainder passing vertically down through passageway 14 which may have a circular or rectangular cross-section. In FIG. 2a, the feed of cooling air is effected through a Venetian-blind-type baffle grid 13, by means of which the angle of impingement of the air on the filaments may be adjusted from 0° to 90° . Here again, the flow of cooling air may be caused by suction or blowing. In the embodiment shown in FIG. 2b, the angle of impingement may again be from 0° to 90° , the air inlet 11, which may be a pressure inlet or a suction inlet, being in the form of an inclined nipple. In the embodiment shown in FIG. 2c, the cooling air is fed to the bundle of filaments by an injector effect, passing in from the ambient atmosphere at small angles down to 0° . It is convenient to place a throttling element 18, for example a grid or gauze, on the upstream side of inlet slot 17. In the embodiment shown in FIG. 2d, the cooling air is blown in parallel to the filaments through a free space in a spinneret 1 or between two adjacent spinnerets 1. In this case, the filaments are cooled from the inside of the bundle. In the last two embodiments it is practically only possible to use pressure blowing. In all of the above described cases, the cooling air, when not already introduced in a direction parallel to the filaments, is deflected at least to a major extent so as to continue its flow parallel to the filaments and thus to effect a primary take-up action in addition to its cooling action, the point of impingement of this take-up air not being directly in the outlet plane of the holes 2 but at a distance of at least 3 to 10 cm therefrom.

In all embodiments, the inlet portions of the cooling zones described above merge into a second zone in the form of a passageway 14, through which the filaments and air pass in parallel directions, the velocity of the air being relatively high. The total length of cooling zone 10, 14 is primarily determined by the polymer used and

by the thicknesses of the filaments and the type of filament (degree of crimping) desired. Suitable lengths are of the order of about 1 to 15 m and preferably about 2 to 10 m. At the end of passageway 14, the cooling air is removed. If the cooling air is pressure-blown into cooling zone 10, 14, it is allowed to escape to the atmosphere through perforated section 15 (see FIG. 1). If, on the other hand, the cooling air is sucked into the cooling zone, a suction chamber surrounds the perforated section 15 and is connected by a suction tube to a suction blower (see FIG. 2a). The cooling zone is closed by adjustable flaps 16, which reduce the outlet cross-section of passageway 14 and thus prevent unwanted air from being sucked in from below. Where the cooling air is applied to the cooling zone by pressure blowing, these flaps 16 may be omitted.

If, in the case of certain raw materials, it is necessary to condition the cooling air, the air extracted from the perforated section 15 or from the moving belt by suction means 61 is passed through an air-conditioning apparatus in which the temperature and humidity are adjusted and the conditioned cooling air is then returned to the cooling channel 10 through feed connection 11, with or without the addition of fresh air.

To the cooling zone 10, 14 there is connected a main take-up apparatus in the form of a single-stage or, preferably, multi-stage pneumatic jet 20 operated by an external air jet. The two-stage embodiment of pneumatic jet 20 shown in FIG. 3 consists of an outer housing 21 with an air inlet connection 22 and an inner tube or channel 27 which is located within the housing 21 and forms, together with damming elements 24, an antechamber or equalizing chamber 23. A cap nut 31 holds inner tube 27 and outer housing 21 together. On each side of damming elements 24 there is located an inlet chamber 25 from which the air passes through inlet passages 26 (slots or bores) to the interior of inner tube 27 at an angle of from 5° to 30°, as a result of which the filaments are drawn in and taken up through the preferably funnel-shaped suction nozzle 29. The distance between the take-up stages is adjusted by means of a screw thread 28 or similar means. The length of the suction nozzle 29 is usually from 5 to 50 times its internal diameter or internal width. The length of inner channel 27 including a diffuser 30 integral therewith, as measured between the two inlet points 26, is approximately the same as that of the suction nozzle 29 and is also approximately the same as that of a connecting piece 41 adjoining pneumatic jet 20 downstream thereof. The end of connecting piece 41 remote from the pneumatic jet is connected to a crimping device 40 which consists of said connecting piece 41 acting as inlet channel, to which there is fitted via axial displacement means, for example a screw thread 42, a member 43 of enlarged cross-section, the increase in cross-section commencing in an undercut and continuing irregularly until a chamber is formed, at the end of which the cross-section again diminishes irregularly, to a final point 45 at which a sharp edge 44 is formed, from which point 45 a short outlet channel 46 extends in the downstream direction. The axial length of the crimping zone 40 is adjusted by means of a setting device 42 in such a manner that the annular or cylindrical vortices formed at point 47 move away from point 47 at a high frequency, drift to point 48 and spring back to point 47 with partial flow-off and replenishment.

The crimping zone 40 is directly connected to a flexible connecting piece 50, for example a plastic hose,

which is fitted with a mouthpiece 51 and is adapted to carry out lay-down motions. The mouthpiece 51 may be a simple tube, a tube which increases in cross-section regularly or irregularly, or a slotted nozzle for fanning out the strand of filaments. Fanning of the filaments may be alternatively effected by directing two of the filament-laden air nozzles at an angle to each other.

An apparatus 59 suitable for the subsequent step of laying down structured non-woven webs is shown diagrammatically in FIG. 4. It is composed of the aforementioned mouthpiece 51, which are connected to the flexible connecting pieces 50 and are also secured to a strip 52 via bearings which permit a tilting movement, for example self-aligning ball bearings, the said strip 52 being in the form of a connecting rod extending between rotating discs 53. The discs 53 are mounted in a frame 54 which also carries the driving unit 55 for the said discs. The frame 54 is suspended for linear reciprocating motion on hanging bars 56 and is hingedly connected to a connecting rod 57 which is in turn pivotally connected, eccentrically, to a driven disc 58. Alternatively, this reciprocating motion may be effected by means of a pneumatic or hydraulic cylinder and piston combination.

Non-woven webs produced by the above combination of superimposed motions have the structure shown in FIG. 5 resulting from the rotating motion with superimposed linear reciprocating motion and the movement of belt 60. Lay-down is preferably effected with overlapping of at least 50%. Such overlapping is not shown in FIG. 5 for the sake of clarity. The spirals drawn in FIG. 5 represent either single crimped filaments or bundles of crimped filaments. To obtain a uniform web, it is recommended to operate a number of the aforementioned spinning units in parallel and to cause the groups of filaments to be laid down in overlapping relationship. The moving belt 60 is preferably provided with suction means 61, this being particularly necessary with webs of high specific weights. The reference numeral 70 indicates a device for effecting mechanical, thermal or chemical bonding of the web, for example by needle punching, steaming, calendering, impregnation (spraying or dipping), followed by drying. To improve the quality of the filaments, a conventional mechanical stretching device having take-up godets and stretching godets may be provided between passageway 14 and pneumatic jet 20.

Threads, yarns and fibers, for example staple fibers, having the features of the filaments produced by the process of the invention and products made therefrom also come within the scope of the present invention.

EXAMPLE 1

Polypropylene having a density of 0.91 g/cm³ and a melt index MI_{2.16} _{kg/190° C} of 2.5 as measured according to ASTM D 1238 - 52 T and provided with a finely divided pigment was fed to a spinneret at a temperature of 280°C and a pressure of 75 atmospheres gage and extruded through a number of holes having a diameter of 0.8 mm. The throughput of melt through each hole was 5 g/min. The filaments were cooled by air blown against them from the side at a pressure of 70 mm of water, in the manner illustrated in FIG. 1. The total cooling zone 10, 14 had a length of 6.5 m and was provided with suction means 15 at its lower end. The two-stage pneumatic jet 20 as illustrated in FIG. 3 had an internal inlet diameter of 5 mm. An adjacent

crimping zone 40 had a diameter of 12 mm and a length of 30 mm. The pneumatic jet was operated at 1 atmosphere gage of air and a specific air consumption of 10 kg/kg of melt. The filaments were passed through a flexible connecting piece 50 and emerged from a mouthpiece 51 which, guided by a moving mechanism 59, executed a rotating motion of 3 c/s and a superimposed linear reciprocating motion of about 0.5 c/s. On moving belt 60 of wire netting, which had suction means 61 below the point where the filaments initially contact the belt, there was formed a web of non-woven fibrous material having a width of about 0.5 m. The weight constancy of the web in its central test area was better than $\pm 5\%$.

The speed of travel of the belt was adjusted so that a web having a weight of 750 g/m² was formed. Some slight needlepunching of the very voluminous, colored web (specific volume 25 cc/g) was carried out and the web was finished by subsection to two further needlepunching operations. There was obtained a needleloom material which, after usual impregnation and provision of backing in the form of waffle foam, was eminently suitable as a floor covering.

EXAMPLE 2

Propylene was fed to a spinneret 1 under the same conditions as mentioned in Example 1, which spinneret had a free space in its center, as illustrated in FIG. 2d, the melt being spun through holes 2 having a diameter of 0.5 mm. The cooling air fed to the center of the assembly was under a pressure of 0.1 atmosphere gage, and the cooling air was sucked off at the end of the cooling zone 10, 14, which had a length of 4 m. Pneumatic jet 20 was of the single-stage type and was connected to a crimping zone 40. The resulting crimped filaments, after passing through the flexible connecting piece 50 and the moving mouthpiece 51, as described in Example 1, were laid down to form a web weighing 400 g/m². The diameter of the filaments was 20 μ m and they possessed from 8 to 10 crimps per cm. Their tensile strength was 3 g/dtex and their elongation was 180%. The web was slightly needle-punched and was then in a condition suitable for use as backing for a further layer of carpet material to be secured thereto by needle-punching in the manufacture of needle-punched floor coverings.

EXAMPLE 3

Polypropylene containing pigment and having a melt index $MI_{2.16}^{kg/100^\circ C}$ of 5.5 was fed to a spinneret 1 having 100 holes 2 with a diameter of 0.5 mm, at a temperature of 260°C and under a pressure of 40 atmospheres gage. Cooling air was fed to the filaments as described in Example 1. The cooling zone 10, 14 was 4 m long and had merely a grid 15 at its lower end to enable the cooling air to escape. Using a two-stage pneumatic jet 20 connected to a crimping chamber 40 and operated at a pressure of 1.8 atmospheres gage, filaments were obtained which had a diameter of 60 μ m and a very fine crimping effect consisting of about 18 to 20 helices of a diameter of about 2 mm in every cm of unstretched filament. Tensile strengths were at 4.5 g/dtex and elongations were below 100%. The filaments were laid down as described in Example 1 to form a web weighing 400 g/m². The web was needle-punched twice and it was given a surface texture by needle-punching in order to give it the appearance of a textile fabric. It was eminently suitable for use as cover

material for upholstery, automobile seats, cushions, etc.

EXAMPLE 4

Polypropylene was fed, under the same conditions described in Example 3, to a spinneret 1 of the kind described in Example 2. The filaments were taken up by a four-stage pneumatic jet 20 having inlet bores 26 of a diameter of 1 mm in its first stage 4, its second stage 6, its third stage 8 and its fourth stage 12. The internal diameter of the pneumatic jet increased by 1 mm from stage to stage. The resulting filament characteristics were approximately the same as obtained in Example 3. The filaments could be laid down to form a web of the same type as that described in Example 3 and having the same applications.

EXAMPLE 5

Polyester having a K value of 61 was fed, at 40 atmospheres gage and 300°C, to a spinneret 1 having bores 2 of 1 mm in diameter. The filaments were cooled by means of a suction fan connected to the bottom end of cooling zone 10, 14 having a length of 3 m. The filaments were taken up by a two-stage pneumatic jet 20 operating at a pressure of 2 atmospheres gage. The resulting filaments were slightly crimped and had a diameter of about 10 μ m and comprised from 3 to 4 helices of 2 mm in diameter per cm of filament. The filaments were laid down to form a voluminous web having a weight of 450 g/m². During the laying down process, the web was sprayed with an aqueous dispersion of a curable acrylic ester such that after drying and curing the web consisted of 90% of filaments and 10% of binder. The coherent, resilient non-woven web thus obtained was highly suitable for use as stuffing in quilts and winter clothing.

EXAMPLE 6

Polycaprolactam having a K value of 72 and a melt viscosity of 3,500 poises at 250°C was fed to a spinneret 1 containing holes 2 having a diameter of 0.6 mm. The cooling system operated by pressure blowing at a pressure of 70 mm of water, the cooling air being blown out to the side at the lower end of the 4 m long cooling zone 10, 14. The two-stage pneumatic jet 20 and crimping zone 40 as used in Example 1 produced filaments having a diameter of 18 μ m and containing from 4 to 5 helices of from 1.5 to 2.0 mm in diameter per cm of filament. The voluminous web produced from these filaments and having a weight of 300 g/m² was lightly powdered with an adhesive, which was cured at 130°C to bond the web. The web was suitable for making air filter mats.

We claim:

1. A process for the manufacture of a non-woven web of spun filaments, consisting of filaments or strands of filaments of synthetic high molecular weight polymeric material, by extrusion of filament-forming melts through spinnerets having a plurality of spinning holes arranged in circles, ellipses or lines, wherein:

a. cooling air is caused to impinge on the extruded filaments from one side at an angle of from 0° to 90° to the direction of travel of the filaments, all or at least part of which air is deflected to a direction of flow parallel to the filaments, by which means the filaments are asymmetrically cooled and a primary take-up of the filaments is effected;

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- b. at the end of the cooling zone substantially all of the cooling air is allowed to escape from or is sucked away from the filaments;
- c. the filaments, substantially free from cooling air, are subjected to the main take-up forces in a take-up zone which is immediately downstream of the cooling zone and is in the form of a single-stage or, preferably, multi-stage pneumatic jet;
- d. the filaments being thereby stretched by the action of said primary and main take-up forces upon them;
- e. after stretching, the partially plastic filaments are helically crimped by periodic alteration of the position of one or more annular or cylindrical vortices of gaseous medium along the filaments at a high frequency with partial flow-off and replenishment of the vortex or vortices in conjunction with said asymmetrical cooling of the filaments whereby the diameter of the helices is from 1 to 10 mm and a

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- change in direction of turn occurs after every 1 to 50 times;
- f. the crimped filaments are discharged through flexibly mounted mouthpieces, which describe a transverse motion with superimposed rotating motion, onto a moving belt preferably provided with suction means at the point at which the said filaments initially contact the belt; and
- g. the laid-down web is bonded.
- 2. A process as claimed in claim 1, wherein the filaments are relaxed and simultaneously cooled after the crimping stage, such that the crimping is fixed as the filaments solidify.
- 3. A process as claimed in claim 2, wherein the pneumatic jets are operated with hot gas or steam or both in order to modify the filament characteristics.
- 4. A process as claimed in claim 3, wherein the strength properties and elongation of the filaments and in some cases the type of crimping obtained are influenced by feeding steam to the cooling zone.

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